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JC20 Rec'd PCT/PTO 31 MAY 2005 [10191/3746]

RECONSTRUCTION OF AN ANGLE SIGNAL FROM THE SENSOR SIGNAL OF A ROTATION ANGLE SENSOR

Background Information

The present invention relates to a method for reconstruction of an angle signal from the sensor signal of a rotation angle sensor according to the preamble of Claim 1 and to a rotation angle sensor system according to the preamble of Claim 6.

Rotation angle sensors are used in a plurality of applications for measuring angular positions of rotating objects. Magnetic or optical sensors which permit contactless measurements are typically used. One application in the automotive industry is, for example, the determination of the steering wheel angle or steering angle of a motor vehicle.

Figure 1 shows a measuring device known from the related art for measuring the rotation angle of a rotating shaft 1 which is rotatable in the direction of arrow A. The measuring device depicted here has a sensor 2 situated on one end of shaft 1, which has an analyzer unit 4 connected to it, sensor 2 cooperating with a stationary transducer 3. Transducer 3 includes in this case a permanent magnet which induces a voltage in sensor 2, for example. Hall sensors, -magnetoresistive sensors (MR sensors), magnetotransistors, etc. may be used as a sensor element.

A typical rotation angle sensor such as often used for detecting the steering wheel angle in a motor vehicle has, for example, the characteristic curve shown in Figure 2a. As the figure shows, the sensor signal α_S of sensor 2 includes the entire measuring range (e.g., steering wheel angle α_L between -800° and +800°), so that the actual steering wheel angle α_L is output at the output of sensor 2, i.e., analyzer unit 4. A steering movement as represented in Figure 2b by reference numeral 6, in which the steering wheel is rotated from zero position ($\alpha_L = 0°$) to the right-hand stop (e.g., $\alpha_L = 800°$) and from there back to zero position is therefore unambiguously displayed by sensor 2. Sensor signal 7 is therefore depicted in Figure 2b as a stepped signal because in this example it is a digitized signal 7.

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Sensor signal 7 may be further processed by additional systems 4 present in the vehicle such as, for example, a vehicle dynamics control system (e.g., electronic stability program ESP).

Sensors 2 having a linear characteristic curve over a large measuring range have the disadvantage that they have a relatively complex design and are therefore expensive.

It is therefore desirable to use other standard sensors of a simpler design for angle measurements which, in particular, need no means for counting full revolutions or recognizing the direction of rotation. Such a sensor may be implemented, for example, by a plurality of MR sensors.

The characteristic curve of such a rotation angle sensor is shown in Figure 3a as an example. As the figure shows, the measuring range of the rotation angle sensor only includes a partial range (from –p to +p) of a total measuring range for a rotation angle α_L. For angles α_L outside of the partial measuring range (e.g., between -120° and +120°), characteristic curve 5 of the sensor is periodically repeated. Characteristic curve 5 has a jump 8 between the individual periods of characteristic curve 5, which may also be called segments S. For example, if the partial measuring range of the rotation angle sensor includes angles between -120° and +120°, rotation angles α_L situated in this range are unambiguously displayed. In contrast, for a rotation angle of 121°, the rotation angle sensor delivers an output signal α_S, identical to that delivered for a rotation angle of -119°.

A rotational movement of a shaft as represented in Figure 3b by reference numeral 6 will thus result in sensor signal 7. It is not possible to directly process such a sensor signal 7 using a downstream device 4 such as, for example, an ESP system, because sensor signal 7 is not unambiguous.

The object of the present invention is therefore to reconstruct, from a sensor signal of a rotation angle sensor having a periodic characteristic curve featuring a plurality of segments, an angle signal which unambiguously renders the actual rotation angle of an object since the initialization of the sensor.

This object of the present invention is achieved by the features recited in Claims 1 and 6. Further embodiments of the present invention are the object of subclaims.

The essential idea of the present invention is to monitor the sensor signal of the rotation angle sensor and to determine positive or negative signal jumps in the sensor signal. In determining the signal jump, a segment value is generated, which specifies in which segment of the sensor characteristic curve the currently measured rotation angle is situated since the initialization of the sensor. An analyzer unit may thus determine the actual total rotation angle (since the initialization of the sensor) in a simple fashion and reconstruct an unambiguous angle signal. A particularly simple and therefore cost-effective rotation angle sensor may thus be used.

According to a preferred embodiment of the present invention, the positive and negative signal jumps in the sensor signal are determined via threshold value monitoring of the rate of change of the sensor signal. This means that a signal jump is assumed when the rate of change of the sensor signal exceeds a predefined threshold value. By comparing the angle values delivered by the rotation angle sensor, it may be determined in a simple fashion whether the jump is positive (from smaller values to larger values) or negative (from larger values to smaller values).

A segment counter is preferably provided, which contains a predefined segment value SN (for example, SN = 0) and which is incremented or decremented in the event of a positive or negative jump. For a sensor characteristic curve such as shown in Figure 3a, the segment counter is preferably incremented by one in the event of a negative signal jump and decremented by one in the event of a positive signal jump.

The analyzer unit may reconstruct the actual angle signal from the instantaneous sensor signal in conjunction with the corresponding segment value in a simple manner. To do so, the processing unit preferably adds an angle, which is a function of the segment value, to the sensor signal. For example, an angle $SN*\alpha(S)$ is added to the sensor signal, SN being the segment value and $\alpha(S)$ an angle corresponding to the segment size.

A rotation angle sensor system according to the present invention includes a rotation angle sensor which has a periodic characteristic curve featuring a plurality of segments between which characteristic curve jumps occur, and a processing unit which is capable of

reconstructing an angle signal, which unambiguously reproduces the actual rotational movement of a device since the initialization of the rotation angle sensor, from the sensor signal and a segment value, the processing unit operating as described previously.

The present invention is elucidated in greater detail below on the basis of the attached drawing as an example.

Figure 1 shows an example of a measuring device for measuring a rotation angle of a rotating shaft;

Figure 2a shows the characteristic curve of a rotation angle sensor known from the related art;

Figure 2b shows the sensor signal of the rotation angle sensor of Figure 2a;

Figure 3a shows the sensor characteristic curve of a known rotation angle sensor having a periodic characteristic curve;

Figure 3b shows the sensor output signal of the sensor of Figure 3a;

Figure 4a shows a sensor signal of a rotation angle sensor having a periodic characteristic curve;

Figure 4b shows the counter content of a segment counter when the signal of Figure 4a is applied;

Figure 4c shows the reconstructed angle signal; and

Figure 5 shows a flow chart showing the essential method steps in reconstructing an angle signal from a sensor signal.

Reference is made to the preamble of the description for elucidating Figures 1 through 3.

Figure 4a shows a sensor signal 7 of a rotation angle sensor 2 having a periodic characteristic curve as shown in Figure 3a as an example. Signal jumps a-d in sensor signal 7 result from the actual rotation angle α_L of shaft 1 going beyond the partial measuring boundaries –p, +p of rotation angle sensor 2. This is elucidated in detail on the basis of an illustrative example.

A system such as that represented in Figure 1 is used, for example, for determining the steering wheel angle of a motor vehicle. Rotation angle sensor 2 is capable, for example, of measuring rotation angles in a partial measuring range of -180 ° (-p) to +180° (+p). This partial measuring range corresponds to segment S0 of the sensor characteristic curve of Figure 3a. Rotation angles outside this segment S0 are displayed in the same measuring range; therefore it is impossible to specify the position in an unambiguous manner, i.e., an angle of +185° will generate the same sensor output value as a rotation angle of -175°.

If the rotational movement of shaft 1 goes beyond segment boundary +p at time t1, the sensor output signal makes a return-jump a to the sensor output value of the next segment S1. The actual rotation angle α_L of shaft 1 is in the time segment t1 to t2, i.e., in segment 1 of the sensor characteristic curve of Figure 3a.

At time t2, rotation angle α_L drops again below the segment boundary between segments S0 and S1. The sensor signal thus jumps at time t2 (Figure 4a) to the end value of segment S0. This positive signal jump is identified using reference symbol b. Therefore, between times t2 and t3 the actual rotation angle is situated in segment S0.

When the shaft rotates further backward, the rotation angle drops below lower segment boundary –p of segment S0 and sensor signal 1 jumps with a positive signal jump c (see characteristic curve of Figure 3a) to the end value of segment S_{-1}. Actual rotation angle α_L is therefore situated in segment S_{-1}.

If the direction of rotation of the shaft is reversed between times t3 and t4, and at time t4 the actual rotation angle exceeds the segment boundary between segment S_{-1} and segment S0, a negative signal jump d occurs in sensor signal 7.

The segment containing the actual rotation angle (since the initialization of sensor 2) is represented using a segment value SN as shown in Figure 4b. The rotation angle sensor system of Figure 1 includes, for this purpose, a segment value counter which has a predefined value (preferably 0) when the rotation angle sensor is initialized and which is either incremented or decremented depending on whether a positive or a negative signal jump occurs in the sensor signal of Figure 4a.

A signal jump is recognized by signal processing unit 4 in that the rate of change of the sensor signal exceeds a predefined threshold value. Processing unit 4 may now reconstruct angle signal 9 shown in Figure 4c in a simple fashion. For this purpose, it adds SN times a segment width, for example, SN*360°, where SN is the segment value, to instantaneous sensor signal 7.

In the previous example it was assumed that shaft 1 is in the zero position when rotation angle sensor 2 is initialized, i.e., in segment S0. In contrast, if shaft 1 is in an angle position outside of segment S0, angle signal 2 must still be corrected by this difference. The offset present at the time of initialization of rotation angle sensor 2 may be taken into account, for example, by storing the shaft position when sensor 2 is turned off (assuming that shaft 1 is not moved while the sensor is turned off).

In the case of a steering wheel angle sensor in a motor vehicle, sensor 2 is initialized, for example, when the ignition is turned on, and sensor 2 is turned off when the ignition is turned off. Since the steering wheel is usually blocked in the parking position when the ignition is turned off, the angular position of the steering wheel when the ignition is turned on corresponds to the previous position of the steering wheel when the ignition was turned off.

Further measures for recognizing an offset of rotation angle sensor 2, such as the use of an additional sensor, for example, are also conceivable.

Figure 5 shows the essential method steps of a method for reconstruction of an angle signal 9 from sensor signal 7 of a rotation angle sensor 2 which has a periodic characteristic curve 3 featuring a plurality of segments S between which characteristic curve jumps 8 occur.

In a first step 15, sensor signal 7 is input, and in step 16 positive and negative signal jumps a-d of sensor signal 7 are detected. When determining a signal jump in step 17, a segment value SN is generated, which specifies in which segment S of sensor characteristic curve 3 the currently measured rotation angle α_L is situated. In step 18 analyzer unit 4 is able to determine the total rotation angle since the initialization of sensor 2 from sensor signal 7 and segment value SN. For this purpose, analyzer unit 4 adds an angle to sensor signal 7, for example, which is a function of segment value SN and the segment width.

Reference Symbol List

1	shaft
2	sensor
3	transducer
4	analyzer unit
5	sensor characteristic curve
6	movement
7	sensor output signal
8	characteristic curve jumps
9	reconstructed angle signal
15-18	method steps
S	segment
SN	segment number
α_L	rotation angle
α_S	rotation angle displayed by the sensor
+p, -p	segment boundaries
t1-t4	times
a-d	signal jumps